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COMPLETE SPECIFICATION

Processes and Alloys for Bonding Titanium-Base Metals to other Metals and Alloys

I, ROGER ALDEN LONG, a citizen of the United States of America, of 24426, Bruce Road, Bay Village, Cuyahoga County, State of Ohio, United States of America, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to improved furnace brazing alloys suitable for forming joints having a high tensile strength at elevated temperatures. The development of the controlled atmosphere furnace brazing process has made possible the application of the furnace brazing processes to the bonding of metals to produce joints with qualities unheard of in the original plain copper and silver alloy braze era. To cite a simple, but important and typical example, the gas turbine compressor blade of aircraft engines may operate at temperatures as high as 800° F., requiring the use of solid forgings and/or castings of nickel-chromium alloys for both the blades proper and their attaching bases. In view of the geographically critical nature of such alloys and the advantages that are obtainable if the base and blade materials could be selected to best perform their individual functions, not only the components, but the bond itself must have the necessary tensile, shear, and stress rupture strength and creep qualities at the elevated temperatures encountered.

Great interest has been shown, for example, in the use of titanium or titanium alloys for the blade material because of the low density of these metals and their strength at elevated temperatures. Obviously, important advantages would be obtainable if the blades could be fabricated by brazing (bonding) blades of a titanium or its alloys with a mounting base formed of stainless steel or the like, or to titanium or titanium alloy parts formed separately by a different method. I have performed wettability and joining tests utilising titanium and its alloys with stainless steel and steel and have found that the characteristics of the braze and interface are similar to the examples that follow.

The behaviour of these metals under forging, casting, machining, and the like, presents problems even if a given piece is to be made entirely of the same material, so regardless of whether titanium is to be joined to itself or to other metals, the nature, behaviour, and characteristics of titanium and its alloys present serious problems for this service, important examples of which are:

(a) Titanium is at present expensive.

(b) Titanium metal oxidizes slightly at room temperatures, the action becoming increasingly rapid as temperatures increase.

(c) Titanium oxide or dioxide resists bonding.

(d) Welding causes embrittlement, and promotes grain growth adjacent to the weld thereby rendering welding unfit for many applications.

A principal object of the invention resides in solving these problems and making possible the furnace bonding of titanium and its alloys to other metals or alloys of different selected characteristics. I have found that this can be accomplished by a process involving assembling the parts to be joined, applying to the joint a ground powder consisting primarily of the nickel-titanium eutectic formed of 66% nickel and 34% titanium, by weight, heating the assembly to approximately 2000° F. for a short period of time and cooling. Alternatively the titanium-nickel eutectic can be used composed of 28% nickel and 72% titanium, by weight, the heating temperature being approximately 1950° F. The cooling rate is variable depending upon the mass of the parts involved, but for a given

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mass, it depends not only upon the characteristics of the titanium alloy itself, but also upon the mass of the joined parts. The titanium element in the eutectic (and to some extent the nickel metal) takes into solution any surface layer of titanium oxide that may exist on the base metal, thus causing the brazing alloy to be self-fluxing or, in other words, to be its own flux to a substantial degree.

Another problem presented by the treatment of titanium and its alloys results from the grain growth that occurs at temperatures at and above about 1800° F. (time dependent), causing embrittlement and other undesirable qualities attendant with coarse grained metals. Thus from the standpoint of grain growth, an alloy having a melting point lower than that of the nickel-titanium eutectic is indicated, provided that other difficulties are not introduced.

In addition to the factor of grain growth, when arriving at a suitable alloy, another characteristic of the eutectic must be considered, namely the tendency of the nickel-titanium eutectic to provide a joint wherein the strength of the braze exceeds that of the interfaces of the joint (the interfaces being the zones of intersolution of base and braze metals). Although the above eutectics do give good joints, in addition to the possibility of grain growth at the temperatures needed for brazing, they provide also a joint with a substantial strength-hardness gradient or variation, when passing from base metal to base metal, which gradient could adversely affect the braze ductility, and fatigue characteristics of the bond.

In addition to the aforesaid object of providing means for joining titanium metals, another object of the invention is to minimize grain growth, reduce the braze strength-hardness gradient (make the strength-hardness factors of the base metals, interfaces as nearly equal as possible) and to attain these advantages while holding to a minimum the porosity of the brazed joint.

In addition to use of the nickel-titanium eutectic referred to, the present invention comprehends a variety of brazing alloy powders based on the 66% nickel—34% titanium eutectic, typical examples of which will be described in detail, as will also examples of the use of the 28% nickel—72% titanium eutectic.

THE EUTECTIC PROCESS.

The use of the nickel-titanium eutectic to solve the problem resulting from titanium oxidation by producing a self-fluxing brazing powder has been explained. This could be formed by grinding into a powder the eutectic produced by mixing titanium oxide and nickel oxide (or powdered metallic nickel) with powdered calcium hydride in a closed reducing retort until particles of the nickel-titanium eutectic are formed. Details of a suitable process (but as applied to the production of nickel-zirconium alloys) are disclosed in the United States Specification No. 2,184,769 (Alexander), said process of formation forming no part of the present invention. The alloy can also be produced by direct alloying of nickel and titanium in correct weight proportions under an atmosphere other than oxidizing and then grinding said alloy to a powder or casting it in a rod form suitable for wire processing.

The ground powder is applied about the joint of the base parts (precleaned if necessary say by etching, wire brushing), and the joint is preferably a shear type joint. A liquid volatile organic binder of a plastic type cement may be used if needed to hold the powder in place. For furnace brazing the prepared assemblage is placed in a brazing furnace and raised to at least the melting temperature of the brazing powder (approximately 1750° F.—2000° F.), and the parts are held at this temperature long enough for the braze alloy and the base parts to inter-dissolve and form an interface. This time depends upon the size of the parts, among other factors, as is known in the brazing art. The atmosphere enveloping the parts while being heated and cooled may be a reducing atmosphere or vacuum but is preferably an inert or substantially inert atmosphere such as one formed of at least 85% helium or argon, the balance usually being hydrogen. The primary function of the atmosphere is to minimize the amount or quantity of titanium oxide, which oxide makes very difficult the production of sound joints. Cooling to room temperature is initiated as soon as experience shows that the brazing material has melted and alloyed to the desired amount, the problem of base metal titanium grain growth also dictating a minimum heating and cooling cycle. The brazed parts are cooled in the inert atmosphere to a temperature sufficiently low so that objectionable oxidation will not occur upon exposure to the air. Where one of the parts comprises titanium, for example, the parts should preferably remain in the inert atmosphere until cooled to 700° F. For torch or induction brazing fluxed or special atmosphere equipment must be used.

In describing the characteristics of the joint produced by the above method as well as that produced by the brazing alloys to be described presently, the base metals joined will be composed each of commercially pure titanium.

THE EUTECTIC JOINT 1950°—2000° F.

Depending on Titanium-Nickel Ratio

Titanium base hardness (Ti brazed to Ti)	20—28 Rockwell C
Braze hardness	43 Rockwell C
Interface hardness	22 Rockwell C
Porosity	Negligible

A joint made with the eutectic process may have a wide application and the production of the brazing powder itself is not complicated. In addition, I contemplate the following processes and methods that produce the aforesaid basic type joint having different properties that will be of interest in various applications.

VARIATIONS IN BRAZING POWDER COMPOSITION.

The alloys to be given as examples hereafter are all various preferred variations in the eutectic alloy of 66% nickel—34% titanium hereinafter to be referred to as the "nickel-titanium eutectic." In accordance with requirements at hand, I shall give representative examples of brazing powders that will meet such various requirements as well as brief discussions of the important desired data that will enable those skilled in this art to determine suitable brazing compositions based upon the characteristics desired.

It was stated that the melting point of the nickel-titanium eutectic is about 2000° F. which in some cases results in base metal grain growth and brittleness (a time dependent function). When titanium or titanium alloys are brazed, I have found that the melting point of the braze material can be lowered by adding to the nickel titanium eutectic a metal of the copper group, namely copper or silver. Copper and manganese may also have a tendency to lower the melting temperature. Copper, however, would ordinarily be selected because of its lower cost. These metals are characterised by having a cubic crystalline structure and a tendency to form solid solutions. The effect on the melting point of adding copper is indicated as the following examples by weight:

TABLE I—MELTING POINT 1850° F.±25° F. (Varies as to Cu content)

Nickel-titanium eutectic	65—75%	
Copper	35—25%	
Ti Base Hardness	20—28	Rockwell C
Braze Hardness	39—40	Rockwell C
Interface Hardness	28	Rockwell C
Porosity	Slight	

The addition of copper has not only lowered the melting point of the braze, and so has in effect reduced grain growth, but has reduced the braze hardness, the braze being the hardest factor in the plain eutectic joint. This might be expected but what is unexpected, the addition of copper has increased the interface hardness, which coupled with a decrease in the braze hardness, materially decreases the hardness gradient between the base, interface and braze zones. These results are of importance. If less copper is added to the eutectic than that shown above, the melting point of the braze is higher. For example, a powder consisting by weight of 92% of the nickel-titanium eutectic and 8% of copper will melt at about 1900° F. Copper (and silver gives similar results) also imparts strength, ductility and soundness to the braze. I have found that more than 35% of copper gives unsatisfactory strength whereas less than 5% does not sufficiently depress the melting point over that of the eutectic.

I have found that the addition of from 2 to 15% of chromium series metals, chromium, iron, manganese, and cobalt, increases the tensile and shear strength of the braze without seriously increasing the melting point, and in some cases tends to smooth out the strength-hardness gradient of the joint. I have also found that beryllium functions when mixed with the eutectic and copper addition to give similar results as those obtained with the series mentioned above. Any tendency toward increased grain growth is counteracted by making the heating and cooling cycles as short as possible.

TABLE III—MELTING POINT 1950°±25° F.

Eutectic	90%
Copper	8%
Chromium	2%
Ti Base Hardness	20—28 Rockwell C
Braze Hardness	25 Rockwell C
Interface Hardness	25 Rockwell C
Porosity	Slight

The braze here is less strong than that of Table I. However, its hardness is reduced markedly, more than in any brazing alloy powder I have tested. The main point here is the levelling out of the hardness gradient across the braze for reasons mentioned previously. The slight porosity of the braze is acceptable in applications where stresses are relatively low.

TABLE III—MELTING POINT—1950°±25° F.

Eutectic	90%
Copper	8%
Manganese	2%
Ti Base Hardness	20—28 Rockwell C
Interface Hardness	25 Rockwell C
Braze Hardness	43 Rockwell C
Porosity	Virtually None

This braze equalled all others in hardness, excelled in porosity (the liquidus and solidus being close together) and although the hardness gradient is slightly higher than that of Tables I and II, the lack of porosity and high strength make this a superior brazing composition.

TABLE IV—MELTING POINT 1950° ±25° F.

Eutectic	80%
Copper	15%
Chromium	5%
Ti Base Hardness	20—28 Rockwell C
Interface Hardness	28 Rockwell C
Braze Hardness	46 Rockwell C
Porosity	Slight

TABLE V—MELTING POINT OVER 1900° F.

Eutectic	80%
Copper	15%
Cobalt	5%
Ti Base Hardness	20—28 Rockwell C
Interface Hardness	36 Rockwell C
Braze Hardness	43 Rockwell C
Porosity	Virtually None

Comparison of Tables IV and V reveals that the material of Table V gives excellent hardness transition from base to interface to braze to interface to base, and further reveals that cobalt is more effective than chromium in this regard, which is somewhat contrary to what would be expected based on the relative behaviour and effects of these two metals in other alloys. This composition in Table V would give excellent high strength braze joints, greater than any yet evaluated.

With regard to the titanium-nickel eutectic, it has been stated that the melting point of the true eutectic is about 1750° F. However, to obtain the exact eutectic analysis is costly and somewhat difficult by known processes. It is therefore often necessary to use "off" eutectic compositions in which the titanium and nickel content may vary from the true eutectic by as much as ±8% per element but preferably only by 4% per element. This off analysis increases the melting point to as high as 2000° F. Since this temperature is excessive for heating titanium or titanium alloys, which heating results in base metal grain growth and brittleness (a time dependent function) the following is found to be desirable. This "off eutectic" alloy, however, will be referred to as "titanium-nickel eutectic" as also will the true eutectic inasmuch as the behaviour of the two is similar. When titanium or titanium alloys are brazed, I have found that the melting point of the braze material can be lowered by adding to the eutectic alloy a metal of the copper group, namely copper or silver. Copper, however, would ordinarily be selected because of its lower cost. These metals are characterised by having a cubic crystalline structure and a tendency to form solid solutions. The effect on the eutectic flow point of adding copper is indicated as follows in Table VI.

TABLE VI.

Titanium-Nickel Eutectic	% Cu Addition	Liquidus and Solidus	Melting Point of (m °F.)
100	0		<1900 >1850
95	5	<50° F	<1900 >1870
90	10	<50° F	<1870 >1850
85	15	<50° F	<1790 >1760
80	20	<50° F	<1760 >1745
70	30	<50° F	<1760 >1745
60	40	<50° F	<1760 >1745
50	50	<50° F	1745±15
40	60	<50° F	1745±15
30	70	<50° F	1745±15

It will be noted that the addition of copper has lowered the melting point of the braze and so has in effect reduced grain growth. Also it is noted that between 10% Cu and 15% Cu there is a rapid drop in flow temperature indicating the possible formation of a tertiary eutectic in this range between Ti—Ni and Cu. Copper (and silver gives similar results) also imparts strength, and soundness to the braze as well as increasing wettability of the braze alloy. I have found that more than 35% of copper gives unsatisfactory properties whereas less than 5% does not sufficiently depress the melting point over that of the titanium-nickel eutectic.

I have found that the addition of metals of the chromium series chromium, iron, manganese and cobalt, increases the strength and other properties, such as ductility and thermal transfer, of the braze without seriously increasing the melting point, and in some cases tends to smooth out the strength-hardness gradient of the joint. I have also found that beryllium functions when mixed with the titanium-nickel eutectic and copper addition to give similar results as those obtained with the series mentioned above and gives age hardening properties to the alloys. Table VII shows the effect of these other metal additions on the flow temperature of the titanium-nickel eutectic with copper.

TABLE VII.

% Titanium-Nickel Eutectic	% Cu Addition	% Mn	% CR	% CO	Flow Temp °F. or Melting Point °F.
85	15				1760—1790
83.3	14.7			2	1760—1790
81.6	14.4			4	1790—1820
78.2	13.8			8	1820—1855
72.2	12.8			15	1870—1900
83.3	14.7		2		1760—1790
81.6	14.4		4		1760—1790
78.2	13.8		8		1790—1820
72.2	12.8		15		1820—1855
83.3	14.7	2			1760—1790
81.6	14.4	4			1760—1790
78.2	13.8	8			1820—1855
72.2	12.8	15			1855—1870

These additions are beneficial as they minimise braze porosity (liquidus and solidus are close together) and improve the solid solution hardness of the eutectic—copper composition. Theoretically, but unproven, these additions with the nickel of the titanium-nickel eutectic tend to keep the copper from forming a specific intermetallic compound with the titanium but allow the formation of a solid solution alloy with a minimum of undesirable phases.

TABLE VIII.

TYPICAL ALLOY.

Composition	
Eutectic 90%	(66%Ti—34% Ni)
Copper 10%	
Flow Temperature	1870° F.
Strength	
Shear Strength	28,200 pounds per square inch
Porosity	None
Wettability at 1870° F.	Excellent

This braze equalled all others in hardness, excelled in porosity (the liquidus and solidus being close together). The lack of porosity and high strength make this an excellent brazing composition.

The examples given employed commercially pure titanium as a base metal but Ti alloy metals may also be brazed. These alloys are generally formed of 92% titanium, balance chromium and manganese at present, but the trend is toward decreasing the titanium factor for cost and economic reasons. Although titanium alloys are stronger than pure titanium, 130,000—175,000 pounds per square inch yield strengths as compared to 75,000 pounds per square inch yield strength for pure titanium, they can be brazed under my invention by taking into consideration the desired melting point, braze strength, and braze hardness gradient and adjusting the temperature lowering and the strength increasing components accordingly. It is to be noted that the heat treating solution temperatures for these alloys are in the neighbourhood of 1750° F. to 1875° F., so that the heat treating step can be combined with the brazing step, which is important from an economy aspect.

EXAMPLES OF TITANIUM BASE METALS.

Examples of titanium base metals other than commercially pure titanium now being commercially offered to the trade are as follows:

1. 2.7% chromium by weight
   1.4% iron by weight
   95.9% titanium by weight
2. 4% manganese by weight
   4% aluminium by weight
   92% titanium by weight
3. 5% aluminium by weight
   5% chromium by weight
   90% titanium by weight.

Where titanium base alloys are solution heat treated at temperatures below about 1850° F. and where a high strength braze is still desired, the substitution of silver metal and/or manganese for part or all the copper would lower the braze temperature sufficiently. A braze of this combination is given in the following Table IX.

TABLE IX—MELTING POINT 1800° ± 50° F.

A.	75%	eutectic
	15%	silver
	10%	copper
B.	75%	eutectic
	20%	silver
	5%	manganese
C.	75%	eutectic
	15%	silver
	5%	copper
	5%	manganese

Another highly desirable characteristic of my brazing alloy is that the effect known in the art as "washing" can be minimised. Washing, refers to that action wherein the braze metal (which it must be remembered is largely nickel in the case of the nickel-titanium eutectic) and the base metal dissolve or alloy into one another to form a new alloy, thereby rendering somewhat inaccurate the original strength and hardness estimates. I have found that the washing effect can be controlled when the nickel-titanium components forming the bulk of the braze powder are not in the 34% Ti—66% nickel combination but differ from this composition, for example, if they are combined in the ratio of 70% nickel to 30% titanium. Then by adding up to 6% of powdered titanium metal by weight, washing is minimized, for these particles are dissolved first by the molten Ni—Ti mixture, and attack upon the base metal tends to be deferred. Although an alloy of this type would have a melting point higher than that of the eutectic, the melting point can be controlled as taught here, by adding metals such as copper, silver and manganese. This alloy has the advantage that the titanium addition by alloying with the near-eutectic composition, counteracts the tendency for the near-eutectic alloy to wash or dissolve heavily the base titanium metal. However, washing can be beneficial and where increased alloying is desired an alloy composition having slightly less titanium than the eutectic composition (up to 4% by weight) would alloy rapidly with the base titanium alloy. It may be advantageous under certain conditions to have an "off eutectic" alloy available.

In the case of the titanium nickel eutectic (which is mainly titanium), I have found that the washing effect can be controlled when the titanium-nickel components forming the bulk of the braze powder are not in the 72% Ti—28% nickel commination but differ from this composition, for example, if they are combined in the ratio of 66% titanium to 34% nickel. Then by adding up to 6% of titanium metal by weight, washing can be minimised. Thus I can take 65—92% by weight of titanium-nickel eutectic (72% Ti and 28% Ni) and add 6% powdered titanium metal, the balance being copper group metal. Although an alloy of this type would have a melting point higher than that of the eutectic, the flow point can be controlled, as taught here, by adding metals like copper and silver. This alloy has the advantage that the titanium addition by alloying with the near-eutectic composition, counteracts the tendency for the near-eutectic alloy to wash or dissolve heavily the base titanium metal. However, washing can be beneficial and where increased alloying is desired, an alloy composition having slightly less titanium than the eutectic com-

position (up to 4—8% by weight) would alloy rapidly with the base titanium alloy. It may be advantageous under certain conditions to have an "off eutectic" alloy available.

Another advantage of utilising the high titanium eutectic is that by dissolving the base metal titanium, you move into a region of titanium-nickel alloys where single solid solution phases are present, thus eliminating the problem of having intermetallic phases at the brazing interfaces.

Other advantages of my braze alloys are that they have a high resistance to oxidation and to chemical corrosion, while silver or copper base alloys are relatively poor in this respect.

In the claims that follow the expression "metals of the copper group" refers to copper and silver, classified in Group I of Mendeleeff's Periodic Arrangement of the Elements. The metal nickel also serves the same function as do the copper group metals, namely lowering of the braze melting point, only when the titanium content of the braze alloy is high and the addition of the proper amount of nickel would lower to the theoretical eutectic composition.

The expression "metals of the chromium series" refers to the metals chromium, manganese, iron and cobalt, arranged in Series 4 of Mendeleeff's Table. The metal beryllium also serves the same function, namely to increase the strength of the joint and to make possible levelling the hardness gradient of the braze, interface and base alloy.

The term "nickel-titanium eutectic" will refer to an alloy 66% to 70% nickel and 34% to 30% titanium that may be prepared as described previously.

The term "titanium-nickel eutectic" will refer to an alloy of 72% titanium and 28% nickel that may be prepared as described previously and also may vary up to $\pm 8\%$ of either constituent in a weight percentage analysis.

Throughout this description the terms "brazing" and "bonding" have been used synonymously. The term brazing originally employed where brass was used as the bonding agent because of its high strength and low melting point as compared to soft solder for instance, is now commonly employed in the art with reference to newer processes wherein the common factor is the joining of base metals by a bonding (brazing) agent that has a melting point lower than that of the base metals and effects a certain surface penetration or intersolution with the faces of the base metals (the interface) to make a joint. The process will be referred to as "bonding" in the claims.

The expression "titanium base metals" as employed in the claims refers to the composition of the base components bonded together which are composed either of pure titanium or of titanium alloys of the general order of those previously described.

What I claim is:—

1. An alloy for bonding together titanium base metals and other metals or alloys to provide a joint having high tensile and shear strength at room and at elevated temperatures, consisting of at least 65% by weight a binary alloy of 66% to 70% nickel and 34% to 30% titanium, the balance, if any, consisting of copper group metal.

2. An alloy for bonding together titanium base metals and other metals or alloys to provide a joint having high tensile and shear strength at room and at elevated temperatures, consisting of at least 65% by weight of a binary alloy of 20% to 36% nickel and 64% to 80% titanium, the balance, if any, consisting of copper group metal.

3. An alloy for bonding together titanium base metals and other metals or alloys to provide a joint having high tensile and shear strength at room and at elevated temperatures, consisting of 65% to 95% by weight of a eutectic of nickel and titanium, the balance consisting of copper group metal.

4. An alloy consisting of 65% to 92% by weight of the nickel-titanium eutectic, and 2% to 15% of a chromium series metal, the balance being copper group metal.

5. An alloy consisting of 65% to 95% by weight of the titanium-nickel eutectic, and 2% to 15% of a chromium series metal, the balance being copper group metal.

6. An alloy for bonding together titanium base metals and other metals or alloys to provide a joint having high tensile and shear strength consisting of a powdered solid solution of alloyed nickel and titanium in the proportion 66% to 70% nickel by weight and 34% to 30% titanium by weight, said solution comprising from 65% to 92% by weight of said nickel-titanium alloy, the balance being a metal of the copper group with or without 2% to 15% of a metal of the chromium series.

7. An alloy for bonding together titanium base metals and other metals or alloys to provide a joint having high tensile and shear strength consisting of a powdered solid solution of alloyed nickel and titanium in the proportion 64% to 80% titanium by weight and 20% to 36% nickel by weight, said solution comprising from 65% to 95% by weight of said titanium-nickel alloy, the balance being a metal of the copper group with or without 2% to 15% of a metal of the chromium series.

8. A powdered composition for bonding together titanium base metals and other metals or alloys to provide a joint having high tensile and shear strength at room temperature and at elevated temperature, consisting of a powdered alloy of 65% to 92%

by weight of titanium and nickel eutectic, said eutectic being in the proportion 72% titanium by weight and 28% nickel by weight, the balance of the alloy being copper group metal, said composition also comprising up to 6% by weight of powdered titanium metal.

9. An alloy for bonding together titanium base metals and other metals to provide a joint having high tensile and shear strength at elevated temperatures consisting of 80% by weight of nickel-titanium eutectic, 15% by weight of a copper group metal and 5% by weight of a chromium series metal.

10. An alloy for bonding together titanium base metals and iron base alloys to provide a joint having high tensile and shear strength at room as well as at elevated temperatures consisting of 80% by weight of a nickel-titanium eutectic, 15% by weight of a copper group metal and 5% by weight of a chromium series metal.

11. A process for bonding together parts formed of titanium base metals, and parts formed of ferrous and/or titanium base metals comprising the steps of applying a brazing alloy consisting of a eutectic of nickel and titanium to a part, bringing the parts together with the eutectic between them, heating the parts in an inert type atmosphere at a temperature of 1750° F. to 2050° F. for a time sufficient to melt the eutectic and form an interface consisting of a solution of the brazing alloy and the parts, and cooling the brazed parts in the inert atmosphere below the oxidation temperature of the part most readily oxidized or to a temperature at which there is no adverse effect on the metals or alloys being brazed.

12. A process for bonding together parts formed of titanium base metals to parts formed of ferrous and titanium base metals comprising the steps of applying a brazing alloy consisting of 65% to 92% by weight of the 66% nickel—34% titanium eutectic and the balance copper group metal to a part, bringing the parts together with the eutectic between them, heating the parts in an inert type atmosphere at a temperature of 1750° F. to 2000° F. for a time sufficient to melt the alloy and form an interface consisting of a solution of the brazing alloy and the parts, and cooling the brazed parts in the inert atmosphere below the oxidation temperature of the part most readily oxidized or to a temperature at which there is no adverse effect on the metals or alloys being brazed.

13. A process for bonding together parts formed of titanium base metals to parts formed of ferrous and titanium base metals comprising the steps of applying a brazing alloy consisting of 65% to 92% by weight of the 72% titanium—28% nickel eutectic and the balance copper group metal to a part, bringing the parts together with the brazing alloy between them, heating the parts in an inert type atmosphere at a temperature of 1745° F. to 2000° F. for a time sufficient to melt the brazing alloy and form an interface consisting a solution of the brazing alloy and the parts, and cooling the brazed parts in the inert atmosphere below the oxidation temperature of the part most readily oxidised or to a temperature at which there is no adverse effect on the metals or alloys being brazed.

14. An article of manufacture comprising a part formed of titanium base metal and one of other metal or alloy, said parts being bonded together by a joint consisting of a thin layer of a eutectic of nickel and titanium merging with an interface consisting of an alloy of said eutectic and the parts.

15. An article of manufacture comprising a part formed of titanium base metal and one of other metal, said parts being bonded together by a joint consisting of a thin layer of an alloy as claimed in any of Claims 1 to 7, or in Claim 9 or 10, said alloy merging with an interface consisting of an alloy of said eutectic and the parts.

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